Paleontological Research, vol. 3, no. 2, pp. 88-94, 3 Figs., June 30, 1999

Boreal-type brachiopod *Yakovlevia* from the Middle Permian of Japan

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Received 15 April 1998; Revised manuscript accepted 25 March 1999

Abstract. **The following three species of the Boreal-type brachiopod genus *Yakovlevia* are described from the Middle Permian (Kungurian to Ufimian) of the Hida Gaien (=Hida Marginal) and South Kitakami Belts, Japan: *Y. kaluzinensis* Fredericks, *Y. mammata* (Keyserling) and *Y. mammatiformis* (Fredericks). The occurrence of *Yakovlevia* together with various Boreal- and Tethyan-type brachiopods in the Middle Permian of the two belts suggests that these regions were probably a continental shelf at the eastern margin of the Sino-Korean block in Middle Permian time.**

Key words: **Boreal-type brachiopod, Hida Gaien Belt, Middle Permian, Sino-Korean block, South Kitakami Belt, *Yakovlevia***

Introduction

Brachiopods are important and useful for Permian global palaeobiogeography as the predominant element in the benthic fauna at that time (Stehli, 1973; Waterhouse and Bonham-Carter, 1975; Grunt, 1995; Shi *et al.*, 1995; Jin and Shang, 1997). *Yakovlevia* is a typical Boreal-type, Middle Carboniferous to Middle Permian productoid genus belonging to the family Yakovleviidae Waterhouse, 1975. This genus was established by Fredericks in 1925, with *Chonetes* (*Yakovlevia*) *kaluzinensis* Fredericks, 1925 from the Middle Permian Chandalaz Formation of Cape Kalouzin in the Vladivostok area, South Primorye as the type species. The morphology and classification of *Yakovlevia* and related genera have been fully discussed by Licharew (1947), Muir-Wood and Cooper (1960), Kotljar (1961), Muir-Wood (1965), Cooper and Grant (1975), Waterhouse (1975), and Shi (1995). Concerning the relationship of *Yakovlevia* with *Muirwoodia* Licharew, 1947, I follow Kotljar (1961), Cooper and Grant (1975), and Shi (1995), all of whom considered *Muirwoodia* as a junior synonym of *Yakovlevia*.

The purpose of this paper is to describe three *Yakovlevia* species, *Y. kaluzinensis* Fredericks, 1925, *Y. mammata* (Keyserling, 1846), and *Y. mammatiformis* (Fredericks, 1926), from the Middle Permian (Kungurian to Ufimian) of the Hida Gaien and South Kitakami Belts, Japan, discussing their palaeobiogeographical significance. The material utilized is: eight specimens of *Y. kaluzinensis* from the lower part of the Moribu Formation in the Moribu area, Hida Mountains (Hida Gaien Belt), central Japan; two specimens of *Y. mammata* from the lower Kanokura Formation in the Kesennuma area, southern Kitakami Mountains (South Kitakami Belt), northeast Japan; and the single specimen of *Y. mammatiformis* from the upper Iriishikura Formation in the Takakurayama area, Abukuma Mountains (South Kitakami Belt), northeast Japan (Figure 1). These specimens are housed in the Department of Geology, Faculty of Science, Niigata University, Niigata (NU-B) and the Institute of Geology and Palaeontology, Tohoku University, Sendai (IGPS).

Palaeobiogeographical significance of *Yakovlevia*

Recently Shi (1995) summarized the stratigraphical and geographical distribution of *Yakovlevia* using 45 species of this genus. According to him, the genus is distributed from the Middle Carboniferous to Middle Permian of the Boreal Realm and the transitional zone between the Boreal and Tethyan Realms, namely, the Northern Transitional Zone (Sino-Mongolian Province) and the Cordilleran Province (see Shi, 1995, figs. 2, 3, table 1). The former transitional zone is almost equal to the Inner Mongolian-Japanese Transition Zone of Tazawa (1991).

As shown in Figure 2, the three *Yakovlevia* species described below clearly indicate a Boreal distribution. *Y. kaluzinensis* has been known from the Middle Permian (Kungurian to Ufimian) of South Primorye, eastern Russia, and the Hida Mountains, central Japan (Fredericks, 1925; Muir-Wood and Cooper, 1960; Kotljar, 1961; Licharew and Kotljar, 1978; Horikoshi *et al.*, 1987; Tazawa, 1987). *Y. mammata* has been known from the Lower Permian (Artinskian) to Middle Permian (Guadalupian) of Spitsbergen; Timan and Pechora, northern Russia; Upper Yukon River, Yukon Territory; Grinnell Peninsula, Devon Island, Arctic Canada; Tien Shan, West China; Ekenalsileng, Jisu (Zhesi), Dong Ujimqin, Xi Ujimqin and Horqin Youyi Qianqi, Inner Mongolia, North China; South Primorye, eastern Russia;

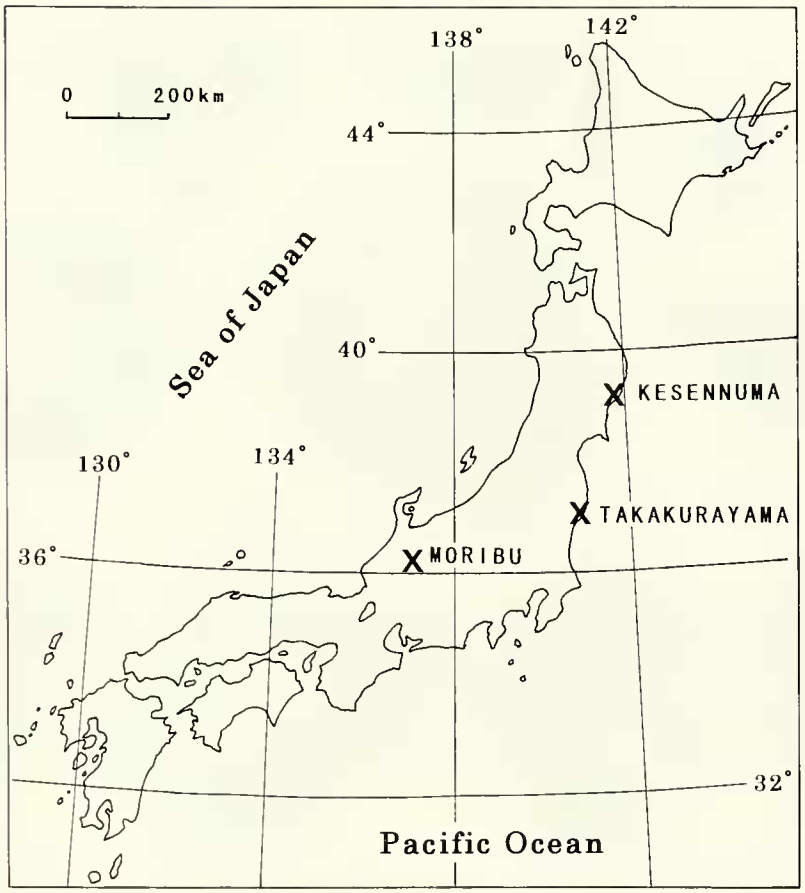

Figure 1. Map showing the fossil localities.

southern Kitakami Mountains, northeast Japan (Keyserling, 1846; Koninck, 1847; Tschernyschew, 1902; Keidel, 1906; Chao, 1927; Grabau, 1931; Stepanov, 1937; Muir-Wood and Cooper, 1960; Harker in Harker and Thorsteinsson, 1960; Kotljar, 1961; Gobbett, 1963; Brabb and Grant, 1971; Ifanova, 1972; Lee and Gu, 1976; Licharew and Kotljar, 1978; Lee and Gu in Lee *et al.*, 1980; Liu and Waterhouse, 1985; Tazawa, 1987; Malkowski, 1988; Zhang, 1990; Nakamura *et al.*, 1992; Kalashnikov, 1993). *Y. mammatiformis* is distributed in the Lower Permian (Sakmarian) to Middle Permian (Kungurian) of the northern Urals, Timan, Pechora Basin and Novaya Zemlya, northern Russia; Omolon Massif, northeastern Russia; South Primorye, eastern Russia; Abukuma Mountains, northeast Japan (Fredericks, 1926; Kotljar, 1961; Mironova, 1964; Yanagisawa, 1967; Zavodowsky and Stepanov in Zavodowsky *et al.*, 1970; Ifanova, 1972; Kulikov, 1974; Kalashnikov, 1983, 1993).

The Middle Permian brachiopod faunas of the Hida Gaien and South Kitakami Belts are characterized by a mixture of Boreal and Tethyan elements, e.g., *Yakovlevia, Cancrinella, Waagenoconcha, Megousia, Stenoscisma*, and *Spiriferella* as the Boreal-type genera, and *Leptodus, Enteletes, Transennatia, Permundaria*, and *Urushtenoidea* as Tethyan-type genera (Tazawa, 1987, 1991, 1992; Nakamura and Tazawa, 1990), and closely resemble those of South Primorye, Northeast China and Inner Mongolia (Tazawa, 1987, 1991, 1992). The occurrence of *Yakovlevia* together with various Boreal- and Tethyan-type brachiopods in the Middle Permian of the Hida Gaien and South Kitakami Belts supports the opinion of Tazawa (1991, 1992), who considered that 1) the above regions belonged to the Southern Subzone of the Inner Mongolian-Japanese Transition Zone, and that 2) this subzone was being probably a piece of continental shelf bordering the eastern margin of the Sino-Korean block, which was situated at a middle northern palaeolatitude in Middle Permian time (Figure 2).

Systematic descriptions

Order Productida Waagen, 1883
Suborder Productidina Waagen, 1883
Superfamily Linoproductoidea Stehli, 1954
Family Yakovleviidae Waterhouse, 1975
Genus ***Yakovlevia*** Fredericks, 1925

Type species.— *Chonetes* (*Yakovlevia*) *kaluzinensis* Fredericks, 1925.

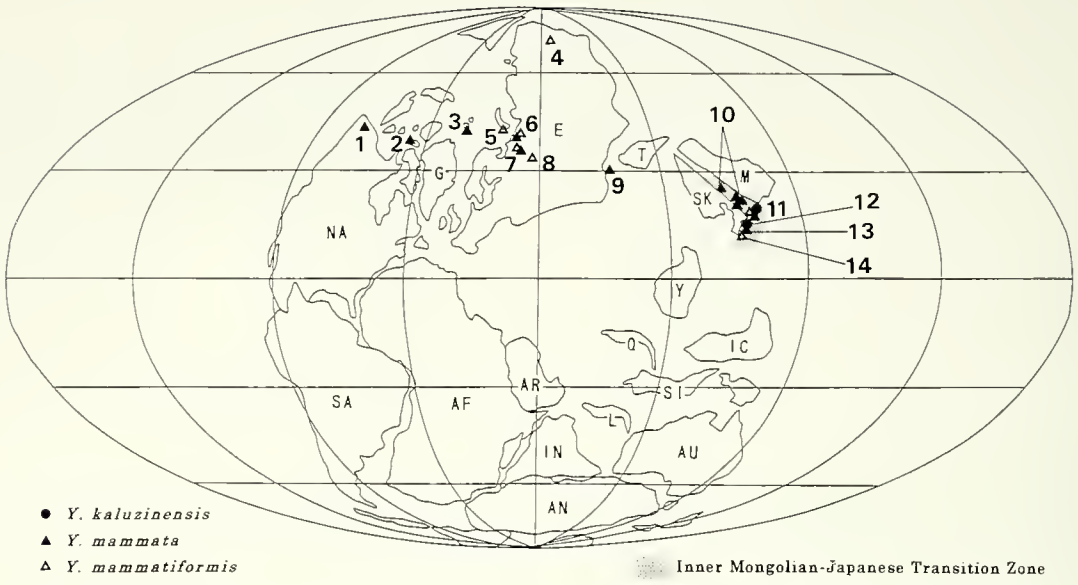

Figure 2. Geographical distribution of *Yakovlevia kaluzinensis* Fredericks, *Yakovlevia mammata* (Keyserling) and *Yakovlevia mammatiformis* (Fredericks) in Middle Permian. (Palaeogeographic map after Ziegler *et al.*, 1996). **1.** Yukon Territory, **2.** Devon Island, **3.** Spitsbergen, **4.** Omolon Massif, **5.** Novaya Zemlya, **6.** Pechora Basin, **7.** Timan, **8.** northern Urals, **9.** Tien Shan, **10.** Inner Mongolia, **11.** South Primorye, **12.** Moribu, Hida Mountains, **13.** Kesennuma, southern Kitakami Mountains, **14.** Takakurayama, Abukuma Mountains. AF : Africa, AN : Antarctica, AR : Arabia, AU : Australia, E : Eurasia, G : Greenland, IC : Indochina, IN : India, L : Lhasa, M : Mongolia, NA : North America, Q : Qangtang, SA : South America, SI : Sibumasu, SK : Sino-Korea, T : Tarim, Y : Yangtze.

Yakovlevia kaluzinensis Fredericks, 1925

Figures 3-7—15

Chonetes (*Yakovlevia*) *kaluzinensis* Fredericks, 1925, p. 7, pl. 2, figs. 64-66.

Yakovlevia kaluzinensis Fredericks. Muir-Wood and Cooper, 1960, pl. 133, figs. 5, 6 ; Kotljar, 1961, text-figs. 1-3 ; Licharew and Kotljar, 1978, pl. 14, figs. 1, 2.

Yakovlevia sp. Horikoshi *et al.*, 1987, text-figs. 3A, B ; Tazawa, 1987, text-fig. 1.7.

Material.—Eight specimens, from the lower Moribu Formation in the Moribu area, Hida Mountains (Hida Gaien Belt), central Japan : (1) external and internal moulds of a pedicle valve, NU-B157 ; (2) internal moulds of three pedicle valves, NU-B158-160 ; (3) external and internal moulds of two brachial valves, NU-B161, 162 ; (4) external moulds of two brachial valves, NU-B163, 164.

Description.—Shell large for genus, transversely subrectangular in outline, with greatest width at hinge line ; length about 37 mm, width about 44 mm in the smaller pedicle valve specimen (NU-B157) ; length 38 mm, width about 60 mm in the largest and best preserved brachial valve specimen (NU-B163).

Pedicle valve gently convex on venter, strongly geniculated, and followed by a long trail. Umbo small. Ears large, prominent, but not clearly differentiated from visceral part. Sulcus narrow and shallow, originating near umbo, and extending to anterior margin. External ornament of pedicle valve invisible except for a row of oblique spines just anterior to the posterior margin. Brachial valve nearly flat on visceral disc, strongly geniculated, and followed by a short trail. Fold narrow and low on anterior half of valve. External surface of brachial valve ornamented by numerous fine costellae and several weak, irregular concentric rugae on visceral disc, costellae only on trail ; costellae often bifurcating and intercalating, numbering 11-13 costellae in 5 mm at midvalve.

Pedicle valve interior with a pair of small, elongate subtrigonal adductor scars and two large diductor scars. Diductor scars striated anteriorly and encircled by a strong ridge posterolaterally. Internal structure of brachial valve obscure in the present material.

Comparison.—The Moribu specimens are referred to *Yakovlevia kaluzinensis* Fredericks, 1925, originally described by Fredericks (1925) from the Middle Permian in size and shape of the shells, especially in the transversely subrectangular outline.

Yakovlevia impressa (Toula, 1875, p. 236, pl. 5, figs. 1a-c) from the Middle Permian of Spitsbergen differs from *Y. kaluzinensis* in having larger and more prominent ears.

Yakovlevia mammata (Keyserling, 1846)

Figures 3-1—5

Productus mammatus Keyserling, 1846, p. 206, pl. 4, figs. 5-5b ; Koninck, 1847, p. 49, pl. 7, figs. 4a-e ; Tschernyschew, 1902, p. 295, pl. 35, figs. 4-6 ; Keidel, 1906, p. 367, pl. 12, figs. 5a,

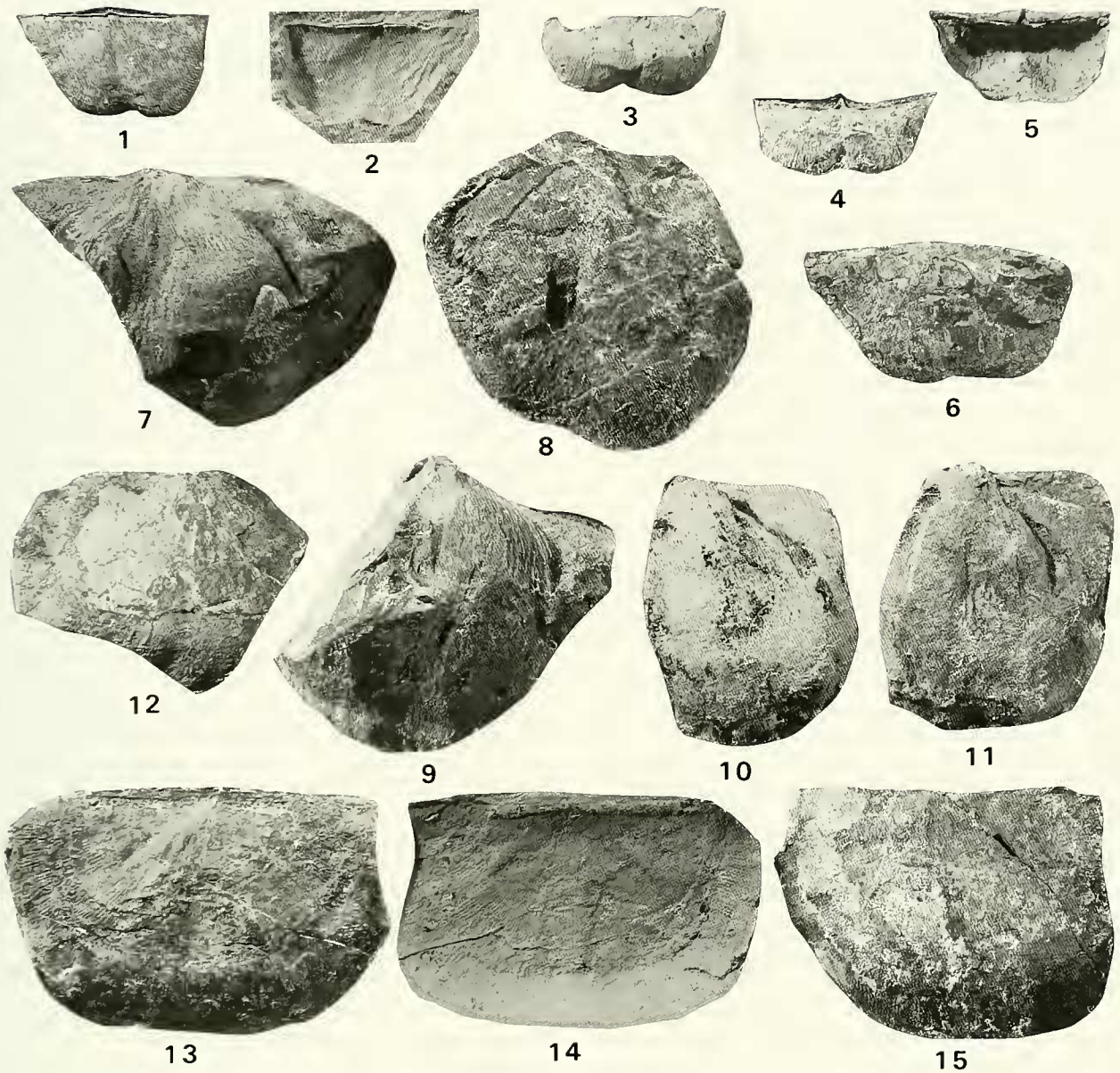

Figure 3. **1**—**5**. *Yakovlevia mammata* (Keyserling). **1, 2**. External mould of a brachial valve and the latex cast, NU-B166. **3**—**5**. latex cast of a pedicle valve exterior, external mould of a brachial valve and the latex cast, NU-B165. **6**. *Yakovlevia mammatiformis* (Fredericks), external mould of a brachial valve, IGPS coll. cat. no. 86649. **7**—**15**. *Yakovlevia kaluzinensis* Fredericks. **7**—**9**. internal moulds of pedicle valve specimens, **7**. NU-B158, **8**. NU-B160, **9**. NU-B159. **10, 11**. external mould of a pedicle valve and the latex cast, NU-B157; **12**. external mould of a brachial valve, NU-B162; **13, 14**. external mould of a brachial valve and the latex cast, NU-B163. **15**. external mould of a brachial valve, NU-B161. (All figures in natural size)

b.

Linoproductus ? mammatus (Keyserling). Chao, 1927, p. 146, pl. 15, figs. 10-14.

Productus (Linoproductus ?) mammatus Keyserling. Grabau, 1931, p. 288, pl. 29, figs. 10-14.

Productus (Thomasina) mammatus Keyserling. Stepanov, 1937, p. 127, 177, pl. 2, figs. 5-7.

Muirwoodia mammata (Keyserling). Muir-Wood and Cooper, 1960, pl. 120, figs. 9-11; Harker in Harker and Thorsteinsson, 1960, p. 58, pl. 16, figs. 1-5; Gobbett, 1963, p. 112, pl. 13, figs. 23-28; Lee and Gu, 1976, p. 263, pl. 159, figs. 7-9; pl. 163, figs. 2a, b; pl. 164, figs. 3-4; pl. 170, figs. 6, 7; Licharew and Kotljar, 1978, pl. 14, figs. 3-5; Liu and Waterhouse, 1985, p. 17, pl. 4, figs. 4-6; Nakamura *et al.*, 1992, pl. 1, figs. 4a, b;

Kalashnikov, 1993, p. 63, pl. 19, figs. 1-3.
Yakovlevia mammatus Keyserling. Kotljar, 1961, text-figs. 4-6.
Yakovlevia mammata (Keyserling). Brabb and Grant, 1971, p. 16, pl. 1, figs. 9-12, 33-36; Ifanova, 1972, p. 121, pl. 7, figs. 4-5; Malkowski, 1988, p. 40, pl. 5, fig. 6; Zhang, 1990, pl. 2, figs. 4, 7, 9.
Yakovlevia paragreenlandica Lee and Gu in Lee *et al.*, 1980, p. 382, pl. 171, figs. 5-7.
Muirwoodia sp. Tazawa, 1987, text-fig. 1.6.

Material.—Two specimens, from the lower Kanokura Formation of Kamiyasse and Omotematsukawa in the Kesennuma area, southern Kitakami Mountains (South Kitakami Belt), northeast Japan: (1) external and internal moulds of a pedicle valve, NU-B165; (2) an external mould of a brachial valve, NU-B166.

Description.—Shell small for genus, transversely subtrapezoidal in outline, with greatest width at hinge line; length 13 mm+, width 28 mm in the pedicle valve specimen (NU-B165); length 16 mm, width 29 mm in the brachial valve specimen (NU-B166).

Pedicle valve moderately and unevenly convex in lateral profile, slightly convex on venter, strongly geniculated, and followed by a short trail. Cardinal extremities acute. Ears large, not clearly demarcated from visceral part. Sulcus narrow and shallow on venter, becoming wide and deep on trail. Brachial valve nearly flat on visceral disc, strongly geniculated, and followed by a short trail. Fold originating at about midvalve, narrow and low on visceral disc, but wide and distinct on trail. External surfaces of both valves ornamented by numerous fine capillae and several weak, irregular, concentric rugae on visceral disc, capillae only on trail; capillae often bifurcated and intercalated, numbering 14-15 capillae in 5 mm at midvalve.

Pedicle valve interior with large, flabellate diductor scars, occupying posterior half of valve, deeply depressed and bounded by marginal ridges posterolaterally. Other internal structures not observed.

Comparison.—The specimen numbered NU-B166, from the lower Kanokura Formation of the southern Kitakami Mountains, was first figured by Tazawa (1987, text-fig. 1.6) as *Muirwoodia* sp., but is now referred to *Yakovlevia mammata* (Keyserling, 1846), originally described by Keyserling in 1846 from the Lower Permian (possibly Sakmarian) of the Pechora Land, northern Russia, on the basis of similarities in size, outline and external ornament.

Yakovlevia paragreenlandica Lee and Gu (in Lee *et al.*, 1980), from the Middle Permian Dashizhai Formation of Horqin Youyi Qianqi, eastern Inner Mongolia may be conspecific with the present species.

The shells described and figured by Grabau (1936, p. 107, pl. 6, figs. 5-6; pl. 11, figs. 4-6) as *Productus mammatus* Keyserling from the Maping Limestone in the Guangxi and Guizhou Provinces, South China differ from *Y. mammata* in having smaller ears and coarser costellae.

Both species, *Yakovlevia artiensis* (Tschernyschew, 1889, p. 279, pl. 7, figs. 29-31) from the Artinskian of the Central Urals and *Yakovlevia greenlandica* (Dunbar, 1955, p. 103, pl. 16, figs. 1-17) from the Middle Permian (Guadalupian) of Central East Greenland are distinguished from the present species by their fewer and coarser costellae.

Yakovlevia mammatiformis (Fredericks, 1926)

Figure 3-6

Productus mammatiformis Fredericks, 1926, p. 87, pl. 3, figs. 4-6.
Yakovlevia mammatiformis Fredericks. Kotljar, 1961, text-figs. 7, 8.
Yakovlevia mammatiformis (Fredericks). Mironova, 1964, p. 97, pl., figs. 14a-v; Zavodowsky and Stepanov in Zavodowsky *et al.*, 1970, p. 114, pl. 35, figs. 8-10; Ifanova, 1972, p. 119, pl. 6, figs. 15-16; pl. 7, figs. 1-2; Kalashnikov, 1983, p. 210, pl. 49, figs. 5, 6, 9; Kalashnikov, 1993, p. 61, pl. 16, figs. 1-4.
Linoproductus cf. *mammatus* (Keyserling). Yanagisawa, 1967, p. 88, pl. 2, fig. 7.
Muirwoodia mammatiformis (Fredericks). Kulikov, 1974, p. 89, pl. 3, figs. 6a-v.

Material.—One specimen, an external mould of a brachial valve, IGPS coll. cat. no. 86649, from the upper Iriishikura Formation in the Takakurayama area, Abukuma Mountains (South Kitakami Belt), northeast Japan.

Description.—Shell medium for genus, transverse, subtrapezoidal in outline, with greatest width at hinge line; length 22 mm, width 42 mm in the brachial valve specimen.

Brachial valve gently concave on visceral disc, strongly geniculated at anterior margin of visceral disc, and followed by a short trail. Ears large, flat and prominent, obscurely demarcated from visceral disc. Fold moderately high, originating at about midvalve, and rapidly widening anteriorly. External surface of brachial valve ornamented by numerous fine costellae; costellae rounded, with narrow interspaces, numbering 10-11 costellae in 5 mm at midvalve. No spines or spine bases observed.

Comparison.—The single specimen from the Abukuma Mountains was first described by Yanagisawa (1967, p. 88) as *Linoproductus* cf. *mammatus* (Keyserling), but this specimen is referred to *Yakovlevia mammatiformis* (Fredericks, 1926) on the basis of its size, shape and surface ornament of the brachial valve.

Yakovlevia mammata (Keyserling, 1846) differs from *Y. mammatiformis* in its smaller and less transverse shell, ornamented by more numerous, fine capillae.

Yakovlevia transversa (Cooper, 1957, p. 39, pl. 5, figs. 1-13) from the Middle Permian of Oregon resembles *Y. mammatiformis* in general appearance, but the former is distinguished from the latter by its smaller dimensions, more developed fold commencing a little below the umbo, and fewer and coarser costellae on the brachial valve.

The shells described as *Y. mammatiformis* from the Middle Permian of Gansu, Northwest China (Ding and Qi in Zhang *et al.*, 1983, p. 292, pl. 99, figs. 9a, b), Inner Mongolia, North China (Lee and Gu, 1976, p. 264, pl. 164, figs. 6, 8; pl. 165, figs. 1, 5) and Heilongjiang, Northeast China (Lee *et al.*, 1980, p. 383, pl. 165, figs. 25a, b; pl. 172, fig. 3) are distinguished from the present species by their much larger size.

Acknowledgements

I thank Guang R. Shi of Deakin University, Melbourne,

Australia for critical reading of the manuscript ; Ei Horikoshi of Toyama University, Yukio Miyake of Miya-mura, Gifu Prefecture and Hiroyuki Ohta of Adachi-ku, Tokyo for providing some of the brachiopod specimens.

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